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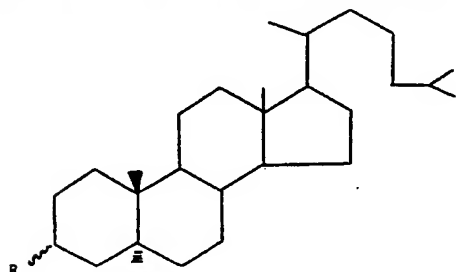
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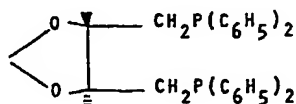
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(54) New steroidal chiral phosphines, methods for their preparation, catalytic systems containing them and catalytic processes in which they are used.

(57) New steroidal chiral phosphines of formula



wherein R represents a phosphorated group selected between

 $\text{CH}_2\text{P}(\text{C}_6\text{H}_5)_2$  and


methods for their preparation; catalytic systems comprising metal complexes and the above steroidal chiral phosphines; asymmetrical catalytic processes like hydrogenation, hydroformylation and hydrocarbalkoxylation of prochiral compounds which employ said catalytic systems.

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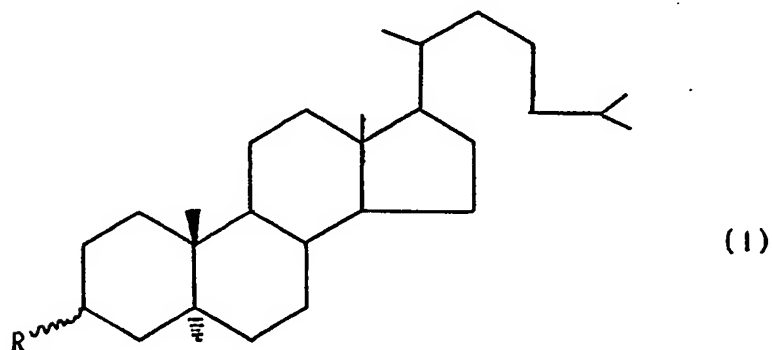
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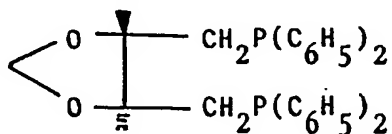
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# DESCRIPTION OF THE INVENTION

The present invention refers to new steroidal chiral phosphines, to methods for their preparation, to catalytic systems comprising metal complexes and the above steroidal chiral phosphines and to asymmetrical catalytic processes like hydrogenation, hydroformylation and hydrocarbalkoxylation of prochiral compounds which employ said catalytic system. More precisely, one object of the present invention is represented by new steroidal phosphines, chiral to the carbon atom, of the general formula



wherein R is a phosphorated group selected between



In the patent literature there are described many phosphines which are used as ligands in catalysts suitable for asymmetric synthesis like asymmetric hydroformylation, asymmetric hydrogenation, asymmetric hydrocarbalkoxylation

and asymmetric hydrosilylation which can be useful in the synthesis of many aminoacids, drugs and pesticides.

German laid open applications 2,161,200 and 2,638,071, US patents 4,008,281 and 4,005,127, Japanese laid open applications 76 88,942 and 78 105,421, describe many phosphines which are used as ligands in catalytic processes for asymmetric synthesis. Processes regarding other asymmetric synthesis in which chiral phosphines are used are also described in German laid open applications 2,359,101, 2,613,817, 2,638,072, 2,638,070, 2,767,671, 2,800,461, 2,909,041, well as US patents 3,849,480, 3,949,000, 3,978,101, 3,968,147. No one of the prior-art phosphines, however, contains any steroidal structure.

The optically active compounds have achieved an increasing importance during the last years in the field of the fine chemicals, mainly of the pharmaceutical compounds. Therefore the importance of regioselective and stereospecific synthetic processes, which allow the production, with high yields, of chiral products from organic prochiral compounds, has considerably increased.

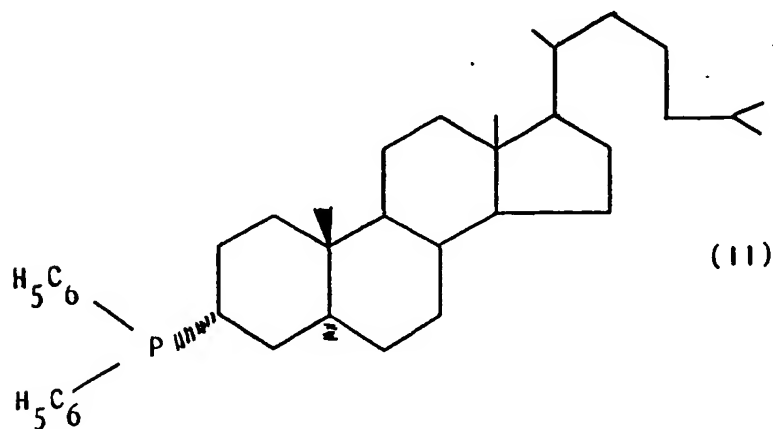
We have now discovered that the new steroidal chiral phosphines of the present invention and, consequently, the new catalytic systems, generally bring to a much higher regioselectivity, in comparison with the known

catalytic systems, in asymmetrical homogeneous catalytic processes. These catalytic systems bring, in some particularly interesting cases, beside a high regioselectivity, to a high stereospecificity thus directly producing optically pure compounds.

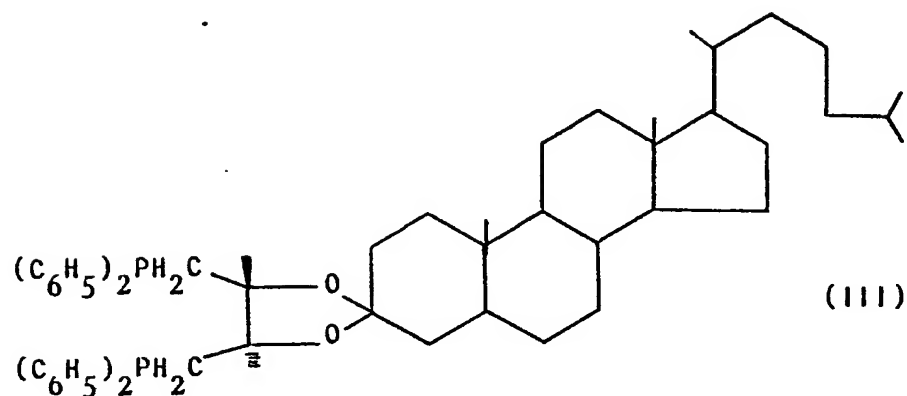
Moreover, these new catalytic systems allow to carry out the catalytic processes in conditions much less drastic than those usually employed.

The new steroidal chiral phosphines, which will hereinafter be referred to as "the new ligands" can be prepared in an easy and cheap way, as they are synthesized in high yields from commercially available starting compounds and easily crystallize, contrary to what generally happens with the known ligands.

Particularly the objects of the present invention are the 3 $\alpha$ -dihenyphosphines-5 $\alpha$ -cholestane of formula

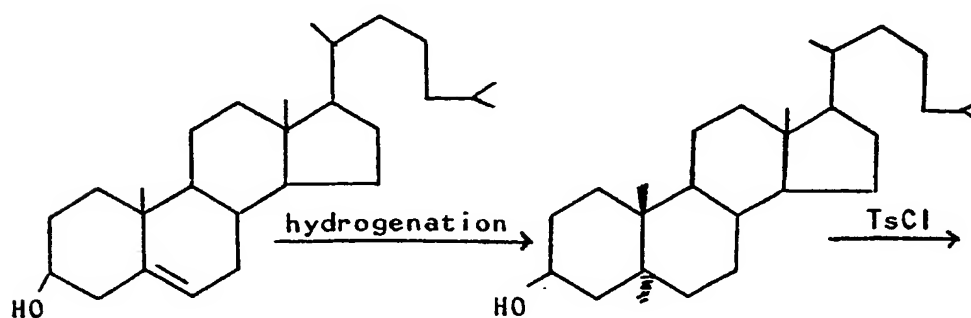


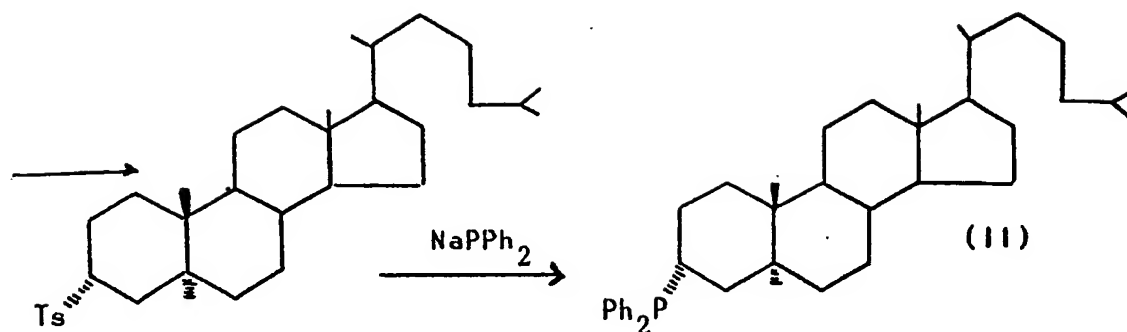
and the 2,3-O-(5')-cholestanylidene-3',3'-dioxy)-1,4-bis-diphenylphosphinebutane of formula



These new optically active compounds which afterwards will be referred to as (+)-DICOL (compound II) and as (-)-DIOCOL (compound III), are both prepared starting from cholesterol and sodium diphenylphosphine through a sequence of reactions.

The following reaction scheme shows the process for the synthesis of (+)-DICOL:





wherein TsCl means tosyl chloride and Ph stands for phenyl.

The first step, namely the reduction, is preferably carried out under hydrogen pressure in the presence of platinum as the catalyst.

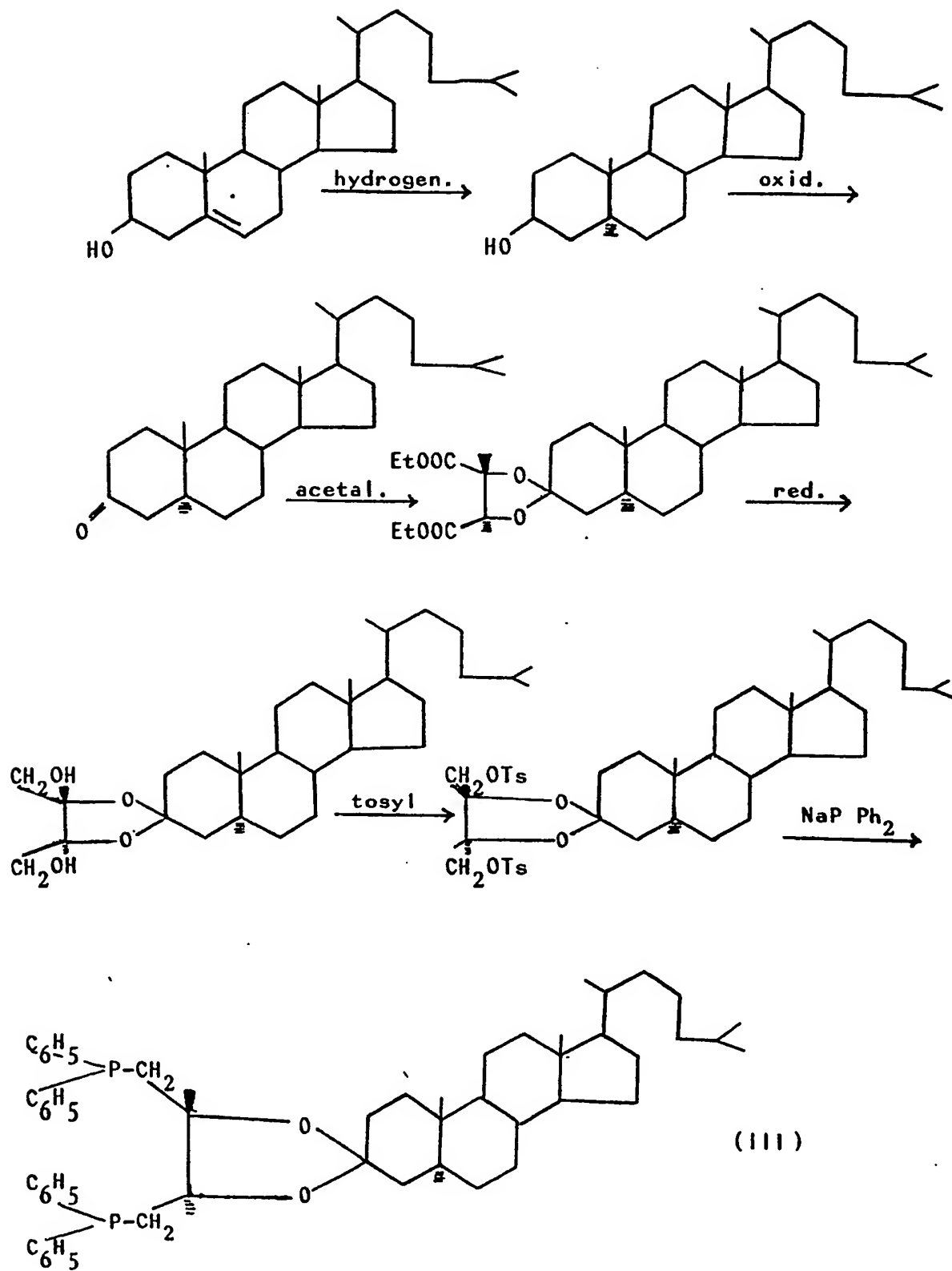
The reaction of 3-hydroxycholestane with sodium diphenylphosphine is preferably carried out by first converting the 3-hydroxy-derivative into its 3-tosyl-derivative through a reaction of the 3-hydroxy-derivative with tosyl chloride in pyridine according to E.B. Hershberg et al. J. Am. Chem. Soc. 73, 1144, (1951) and J. Maunowicz et al. Chem. Listy 52, 2359, (1958).

It is also possible to protect the 3-hydroxy group with other active groups like brosyl, mesyl, triflyl, O.phthalyl, halo, acetyl or other aliphatic or aromatic ester groups.

The so obtained  $5\alpha$ -cholestan- $3\beta$ -ol tosyl ester is reacted with sodium diphenylphosphine, which is prepared in situ from chlorodiphenylphosphine and sodium according to H.B. Kagan et al. J. Am. Chem. Soc. 94, 6429 (1972), thus obtaining in selective way the (+)-DICOL.

The reaction is carried out under nitrogen atmosphere in an anhydrous inert organic solvent like dioxane or tetrahydrofuran or a mixture thereof, preferably a 2:1 (v/v) dioxane/tetrahydrofuran mixture, at ambient temperature for a period of time comprised between 2 and 4 days, preferably 3 days. After working up the reaction mixture, (+)-DICOL is obtained with a yield never lower than 50%, in any case higher than those obtained in the synthesis of other known ligands like neomenthyl-phosphine or menthyl-phosphine; moreover the purification does not show particular problems owing to the fact that (+)-DICOL crystallizes out from the reaction medium in an easy way.

The following reaction scheme shows the process for the synthesis of (-)-DIOCOL:





The hydrogenation of the cholesterol is preferably carried out under hydrogen pressure in the presence of platinum as the catalyst. The so obtained  $5\alpha$ -cholestane- $3\beta$ -ol is then oxidated to the corresponding  $5\alpha$ -cholestane- $3$ -one, preferably by means of an alkali bichromate and sulphuric acid, according to L. F. Fieser and M. Fieser, Org. Synth. Coll. II, 139. The  $5\alpha$ -cholestane- $3$ -one is subsequently transformed into the corresponding acetal by reaction with (R)(R)-diethyl tartrate in an organic solvent like toluene or benzene in presence of p-toluenesulfonic acid at the boiling temperature of the reaction mixture for a period of time comprised between 12 and 24 hours, preferably 18 hours. The carbethoxy groups of the resulting product are subsequently reduced to hydroxymethyl groups by means of a metal hydride such as, for instance, lithium aluminium hydride or sodium borohydride and analogs, preferably lithium aluminium hydride in anhydrous diethyl ether at the boiling temperature of the reaction mixture for a period of time comprised between 2 and 10 hours, preferably 4 hours. The so obtained 2,3-O-( $5'\alpha$ -cholestanylidene)-L-treitol is then transformed into the corresponding ditosyl derivative by means of tosyl chloride in pyridine. The hydroxy

groups can be protected also by transforming them into the brosyl, mesyl, triflyl derivatives or into the labile esters of aromatic or aliphatic acids.

The last reaction step contemplates the introduction of the diphenylphosphinic groups by reacting the ditosyl-derivative with sodium diphenylphosphine, thus obtaining in a selective way the (-)-DIOCOL, 2,3-O-(5' $\Delta$ -cholestanylidene-3',3'-dioxy)-1,4-bis-diphenylphosphinebutane, with very high yields, usually higher than 90% of theoretical. This reaction is carried out by reacting 2,3-O-(5' $\Delta$ -cholestanylidene)-L-treitol-1,4-bis-p-tosylate with sodium diphenylphosphine under stirring at room temperature in an anhydrous inert organic solvent like dioxane or tetrahydrofuran or a mixture thereof, for a period of time comprised between 24 and 72 hours, preferably 48 hours. After working up the reaction mixture the pure (-)-DIOCOL is obtained with a yield of 90%.

The preparation of compounds (II) and (III) having a high optical purity, at least higher than 95%, is of paramount importance for the purpose of the present invention, as the presence of great quantities of other epimers alters in a determinant manner the stereoselectivity of the subsequent processes of asymmetric catalysis.

The new ligands obtained as previously described are used according to the present invention in processes of transformation of prochiral substrata into chiral compounds, by means of known catalytic precursors.

The new catalytic systems are prepared in situ, by mixing the catalytic precursor together with the new ligand; subsequently the substratum is introduced and the process takes place.

Some asymmetric processes which can be carried out by means of the new catalytic systems will be hereinbelow examined in detail. This constitutes another aspect of the present invention.

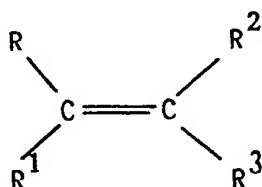
A) Asymmetric hydrogenation of prochiral substrata

The hydrogenation of  $\alpha,\beta$ -unsaturated acids and esters is of particular interest in the field of homogeneous hydrogenations, since it brings to a number of chiral compounds which are much important for pharmaceuticals and pesticides.

Processes of asymmetric hydrogenation of prochiral substrata have already been realized by using catalytic systems made by rhodium and phosphines, chiral to carbon and phosphorus atoms. The new catalytic systems of the present invention, when employed in many industrially interesting cases, like the hydro-

genation of  $\alpha$ -acylaminoacrylic acids, allow to significantly improve the stereoselectivity of the process and thus, in this specific case, to prepare  $\alpha$ -aminoacids or derivatives thereof with a higher optical purity.

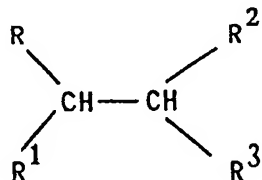
In a representative experiment, we have carried out the asymmetric hydrogenation of compounds of general formula:



wherein R and R<sup>1</sup>, independently represent hydrogen, straight or branched (C<sub>1-6</sub>) alkyl, substituted or unsubstituted aryl, or (C<sub>3-8</sub>) cycloalkyl; R<sup>1</sup> may be also a carboxy group; R<sup>2</sup> represents a carboxy, an ester or an amide group;

R<sup>3</sup> represents (C<sub>4-6</sub>)alkyl, (C<sub>3-8</sub>)cycloalkyl a substituted or unsubstituted aryl or an amide group;

in order to synthesize compounds of formula:



wherein R, R<sup>1</sup>, R<sup>2</sup>, R<sup>3</sup> are defined as above, by means of catalytic systems made by neutral or cationic mono-

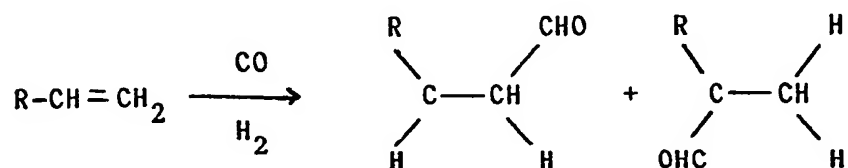
valent rhodium complexes and ligands according to formula (I) or, more precisely, formula (II) and (III). Suitable catalytic precursors are, for instance, cyclooctadienyl-rhodium chloride dimer of formula  $[\text{Rh}(\text{COD})\text{Cl}]_2$ , norbornadienyl-rhodium chloride dimer of formula  $[\text{Rh}(\text{NBD})\text{Cl}]_2$  or cationic complexes of formula  $[\text{Rh}(\text{diolefin})_2]^+\text{ClO}_4^-$ ,  $[\text{Rh}(\text{diolefin})_2]^+\text{BF}_4^-$ ,  $[\text{Rh}(\text{diolefin})_2]^+\text{PF}_6^-$ .

The process is carried out in organic solvents like aromatic or aliphatic hydrocarbons, alcohols, ethers or mixture thereof, preferably a 1:1 (v/v) mixture of benzene and methanol, in the absence of air, under a hydrogen pressure comprised between 1 and 70 atmospheres, at a temperature comprised between 20°C and 50°C and for a period of time comprised between 12 and 24 hours. The nature of the enantiomer excess (ee) depends on the catalytic precursor, the ligand and the used substratum and cannot be foreseen a priori.

#### B. Asymmetric hydroformylation of prochiral substrata.

Processes of asymmetric hydroformylation with carbon-monoxide (CO) and hydrogen (H<sub>2</sub>) were carried out on prochiral substrata, by using rhodium or platinum complexes as the catalysts. Nevertheless the obtained results were unsatisfactory since the optical yields

were in general very low, i.e. not higher than 35%. On the other hand, in a further representative experiment it was found that by using a catalytic system comprising the art known metal complexes and the new ligands, products with the same optical yields were obtained, but a very high regioselectivity towards the formation of the chiral isomer was also achieved. The process runs according to the following scheme:



wherein R is an aliphatic straight or branched alkyl group from 1 to 20 carbon atoms or a substituted or unsubstituted aryl group.

The hydroformylation process is carried out in an autoclave by dissolving the starting material in an organic inert solvent like an aliphatic or aromatic hydrocarbon, preferably mesitylene, in presence of a catalytic amount of a ligand of formula (II) or (III) and of a metal catalyst, in the absence of air under a carbon monoxide/hydrogen pressure comprised between 70 and 100 atmospheres, being the carbon monoxide and

the hydrogen present in equimolecular ratios, at a temperature comprised between 20°C and 100°C, preferably at a temperature between 60°C and 100°C, for a period of time comprised between 4 and 240 hours. The obtained reaction products can be purified by rectification or can be transformed into the corresponding acids by oxidation with silver oxide ( $\text{Ag}_2\text{O}$ ) and subsequently recovered as methyl esters. Particularly interesting results were obtained in the hydroformylation of the styrene and of the isoprene. Also in this case it is impossible to foresee the configuration of the prevailing enantiomer.

C. Asymmetric hydrocarbalkoxylation of prochiral substrata.

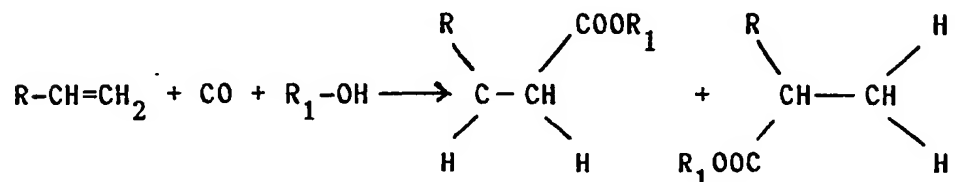
Processes as above defined were already performed by using palladium complexes as the catalysts and chiral phosphines as ligands. Also in this case the values of asymmetric induction were always unsatisfactory (never higher than 68%), which, anyhow, did not depend on the used substratum.

We have now discovered in a third representative experiment that the hydrocarbalkoxylation of olefins, employing the new catalytic systems according to the present invention, comprising the conventional pal-

ladium complexes and the new ligands, a very high regioselectivity towards the chiral compounds was achieved, and this is absolutely interesting from an industrial point of view, also if noteworthy improvements in the reaction stereospecificity are not observed.

The new catalytic systems gave very interesting results in particular in the synthesis of 2-aryl-propionic acids which are, notoriously widely used anti-inflammatory drugs.

The process runs according to the following scheme:



wherein R represents an aliphatic straight or branched group from 1 to 20 carbon atoms or a substituted or unsubstituted aryl group,  $R_1$  represent an aliphatic straight or branched group from 1 to 6 carbons.

The hydrocarbalkoxylation process is carried out in autoclave, by dissolving the substratum, the catalyst and the alcohol in an inert organic solvent, preferably an aromatic or aliphatic hydrocarbon, more preferably benzene, and then introducing carbon monoxide until a pressure of 140 atmosphere is reached, at



room temperature. The autoclave is then heated at a temperature comprised between 80°C and 120°C., and the heating is stopped when the gas absorption ceases. The reaction derivatives are collected by distillation after evaporation of the solvent and are further purified by rectification. Particularly suitable catalytic precursors to be used together with the steroidal phosphinic ligands according to the invention are:  $\text{PdCl}_2$ ,  $\text{Pd}(\text{PPh}_3)_2\text{Cl}_2$ ,  $\text{Pd}(\text{OCOCH}_3)_2$ ,  $\text{Pd}(\text{PhCN})_2\text{Cl}_2$  and the like.

The following examples are provided for with the purpose of better illustrating the various aspects of the invention, but in no way they must be construed as a limitation of the scope of the invention itself.

#### EXAMPLE 1

##### 3 $\alpha$ -diphenylphosphine-5 $\alpha$ -cholestane ((+)-DICOL)

A solution of 25 g (0.046 moles) of 5 $\alpha$ -cholestan-3 $\beta$ -ol tosylate, obtained from cholesterol according to E.B. Hershberg et al., J. Am. Chem. Soc. 73, 1144, (1951) and J. Maunowicz et al., Chem. Listy 52, 2359 (1958), in a 2:1 (v/v) mixture of anhydrous dioxane/tetrahydrofuran was added dropwise, under nitrogen atmosphere, to a solution of sodium diphenylphosphine in 150 ml of a 2:1 (v/v) mixture of anhydrous dioxane/tetrahydrofuran.

The sodium diphenylphosphine was obtained in situ from 14.13 g (0.064 moles) of chlorodiphenylphosphine and 7.06 g (0.307 atoms) of metal sodium according to H.B. Kagan et al., J. Am. Chem. Soc. 94, 6429, (1972).

The reaction mixture was stirred at ambient temperature for a period of time of 72 hours and, after addition of 50 ml of diethyl ether, filtered in order to eliminate the inorganic salts. The solvent was evaporated off under vacuum and the residue was taken up with 200 ml of diethyl ether and again filtered. The filtrate was then added with 120 ml of methanol and the resulting mixture was evaporated until a precipitation of a solid product was achieved. After recrystallization from a mixture of diethyl ether and methanol, 15.8 g of product were obtained, with a yield of 60%, calculated over the starting tosylate.

The physical-chemical properties of the compound were as follows:

m.p.  $129^{\circ}\text{C} \pm 131^{\circ}\text{C}$ ;

$^1\text{H}$ -NMR: most significant resonance peaks were observed at 7.62-7.12 p.p.m. (multiplet, 10 H, aromatic) and at 2.81-2.5 p.p.m. (multiplet, 1 H, H in 3-position)

Mass Spectrum  $\text{M}^+$  556 (Relative intensity (Rel. int.) 100%)

$$[\alpha]_D^{20} = +22^{\circ}.0 \quad (C = 0.986 \text{ in dioxane})$$

All these data are in accordance with the compound of formula (II), (+)-DICOL.

#### EXAMPLE 2

#### 2,3-O-(5'-cholestanylidene-3',3'-dioxy)-1,4-bis-diphenylphosphinobutane ((-)-DIOCOL

50 Grams (0.13 moles) of 5-cholestan-3-one, prepared from cholesterol according to L.F. and M. Fieser, Org. Synth. Coll. II, 139, were dissolved in 4000 ml of anhydrous benzene together with 100 ml (0.58 moles) of L(+)-diethyl tartrate and 100 mg of p-toluene-sulfonic acid and the resulting mixture was refluxed for 18 hours. After the theoretical amount of water formed, the solution was cooled, neutralized and evaporated under vacuum to dryness. The residue was taken up with water, filtered and the precipitate was twice crystallized from a mixture of dichloromethane and methanol.

The 2,3-O-(5'-cholestanylidene)-L-tartrate was obtained, with a yield of 90% of theoretical.

m.p. 103°C-104°C;

$$[\alpha]_D^{20} = +4^{\circ}.24 \quad (C = 1 \text{ in dioxane});$$

Mass Spectrum  $M^+$  574 (Rel. int. 21%).

A suspension of 7 g (0.184 moles) of lithium aluminium hydride in 350 ml of anhydrous diethyl ether was added dropwise with a solution of 42 g (0.073 moles) of diethyl-2,3-O-(5 $\alpha$ -cholestanylidene)-L-tartrate in 350 ml of diethyl ether, under an inert atmosphere.

After refluxing for 4 hours, the reaction mixture was cooled and added with 7 ml of water and 7 ml of a 15% aqueous solution of sodium hydroxide.

The inorganic precipitate was filtered and washed with diethyl ether. The filtrates were collected and evaporated to dryness and the obtained residue was crystallized from a mixture of dichloromethane and methanol.

A further crystallization from a mixture of diethyl ether and hexane gave the 2,3-O-(5 $\alpha$ -cholestanylidene)-L-treitol having m.p. 199°C-200°C,  $[\alpha]_D^{20} = +13^{\circ}.88$  (C = 1 in dioxane), Mass Spectrum  $M^+$  490 (Rel. int. 17%) with a yield of 60% of theoretical.

A solution of sodium diphenylphosphine in a mixture of dioxane and tetrahydrofuran was added dropwise, under stirring at ambient temperature under nitrogen atmosphere, with a solution, in anhydrous tetrahydrofuran, of 23.4 g (0.0295 moles) of 2,3-O-(5 $\alpha$ -cholestanylidene)-L-treitol-1,4-bis-p-toluenesulfonate, obtained with a 95% yield by treating the above 2,3-O-(5 $\alpha$ -cholesta-

nylidene)-L-treitol with p-toluenesulfonyl-chloride in pyridine. The solution was kept under stirring for 48 hours and then poured dropwise in 50 ml of anhydrous ethanol. The solvents were evaporated off in vacuo and the residue, taken up with water, was filtered. The solid was washed with ethanol, dried under vacuum and then dissolved in anhydrous diethyl ether and dried over anhydrous sodium sulphate. After a crystallization from a mixture of diethyl ether and ethanol, 22 g, (90% of theoretical), of pure product were obtained, having the following physical-chemical properties:

m.p. 137°C+140°C;

$^1\text{H}$ -NMR shows the most significant peaks at 7.45+7.05 p.p.m. (multiplet, 20 H, aromatic), 3.98+3.81 p.p.m. (multiplet, 2 H, CHO) and 2.61+2.15 p.p.m. (multiplet, 4 H,  $\text{CH}_2\text{-P}$ );

$[\alpha]_{\text{D}}^{25} = 17.7$  (C = 1.51 in dioxane)

All these data are in accordance with the compound of formula (III), (-)-DIOCOL.

### EXAMPLE 3

Asymmetric hydrogenation of (Z)-acetylamino cinnamic acid.

5 m.moles of (Z)-acetylamino cinnamic acid, 0.05 m.moles

of  $[(\text{COD})\text{RhCl}]_2$  (cyclooctadienyl rhodium chloride dimer) and 0.055 m.moles of (-)-DIOCOL were poured into 250 ml stainless steel autoclave.

After removing the air by means of a mechanical pump, 40 ml of a 1:1 (v/v) mixture of benzene and methanol were introduced by suction, the autoclave was filled with 70 atmospheres of hydrogen and subsequently kept under stirring overnight at ambient temperature. Once the reaction was terminated the solvent was evaporated off under vacuum and the residue was taken up with an aqueous 5% sodium bicarbonate solution. The solution was extracted with diethyl ether and the aqueous layer, after separation, was acidified by means of a 10% aqueous solution of hydrochloric acid.

The acidic solution was then thoroughly extracted with diethyl ether and the organic extract was dried over sodium sulphate. By evaporating off the solvent, 4.5 m. moles of (-)-N-acetyl(R)-phenylalanine were obtained, having  $[\alpha]_D^{25} = -41^{\circ}.9$  (con. = 1 in ethanol), corresponding to an optical purity of 91%.

#### EXAMPLE 4

##### Asymmetric hydrogenation of (E)- $\beta$ -methylcinnamic acid

By operating substantially according to the procedure of Example 3, the (-)-(R)-3-phenylbutanoic acid was ob-

tained, with a yield of 92%, having  $[\alpha]_D^{25} = -4^{\circ}.77$  ( $C = 6$  in chloroform), corresponding to an optical purity of 10.8%, starting from the (E)- $\beta$ -methylcinnamic acid ((E)-3-phenyl-2-butanoic acid).

#### EXAMPLE 5

##### Asymmetric hydrogenation of the mesaconic acid

By operating substantially according to the procedure of Example 3, the (+)-(R)-methylsuccinic acid was obtained, with a yield of 70%, having  $[\alpha]_D^{25} = +1^{\circ}.15$  ( $C = 4.68$  in ethanol), corresponding to an optical purity of 9.2%, starting from (E)-methyl-2-butenedioic acid (mesaconic acid).

#### EXAMPLE 6

##### Asymmetric hydrogenation of the methyl ester of the (Z)-acetylaminocinnamic acid

The hydrogenation reaction was carried out substantially as described in Example 3.

The reduction product was isolated according to the following procedure.

The reaction mixture, after evaporating off the solvent under vacuum, was dissolved in 15 ml of diethyl ether and filtered through a chromatographic column containing a 3 cm thickness of silica gel. By evaporating off the filtrate (-)-N-acetyl-(R)-phenylalanine methyl ester

was obtained, with a yield of 75%, having  $[\alpha]_D^{25} = -2^{\circ}.78$  (C = 2 in methanol), corresponding to an optical purity of 18%.

#### EXAMPLE 7

##### Asymmetric hydrogenation of (Z)-acetylaminocinnamic acid.

5 m.moles of (Z)-acetylaminocinnamic acid, 0.05 m.moles of  $[(\text{COD})\text{RhCl}]_2$  and 0.11 m.moles of (+)-DICOL were poured into a 250 ml stainless steel autoclave.

After removing the air by means of a mechanical pump, 40 ml of a 1:1 (v/v) mixture of benzene and methanol were introduced by suction, the autoclave was filled with 70 atmospheres of hydrogen and subsequently kept under stirring overnight at ambient temperature.

Once the reaction was terminated, the solvent was evaporated off under vacuum and the residue was taken up with an aqueous 5% sodium bicarbonate solution.

The solution was extracted with diethyl ether and the aqueous layer, after separation, was acidified by means of a 10% aqueous solution of hydrochloric acid. The acid solution was then thoroughly extracted with diethyl ether and the organic extract was dried over sodium sulphate.

By evaporating off the solvent, 4.8 m.moles of almost racemic N-acetylphenylalanine were obtained with a yield of 96% of theoretical.



EXAMPLE 8Asymmetric hydrogenation of (E)- $\beta$ -methylcinnamic acid

By operating substantially according to the procedure of Example 7, almost racemic 3-phenylbutanoic acid was obtained with a yield of 96%, starting from (E)- $\beta$ -methylcinnamic acid.

EXAMPLE 9Asymmetric hydroformylation of 1-butene.

$1 \times 10^{-4}$  Moles of  $\text{HRh}(\text{CO})(\text{PPh}_3)_3$  and  $3 \times 10^{-4}$  moles of (+)-DICOL were introduced into a 0.2 liters stainless steel autoclave. The air was then removed by means of a mechanical pump, 40 ml of mesitylene were introduced by suction and finally, after cooling the autoclave to  $-30^\circ\text{C}$ , the reaction mass was added with 0.1 moles of 1-butene. The autoclave was loaded with an equimolecular mixture of carbon monoxide and hydrogen at ambient temperature, reaching a pressure of 90 atmospheres, and the whole was subsequently heated to  $60^\circ\text{C}$  by means of an oil bath. The practically complete (99%) conversion of the starting substratum was achieved in 16 hours. The 2-methylbutanal was obtained as the sole product of the hydroformylation with a yield of 90% by rectifying the reaction mixture. The optical purity of the obtained aldehyde was determined by oxidizing it with silver oxide

and sodium hydroxide to the corresponding 2-methylbutanoic acid and by measuring its optical activity: the prevailing enantiomer showed an (S) configuration and the enantiomeric excess was 1%.

The reaction conditions and the results obtained in the asymmetric hydroformylation (carried out substantially as described in this example) of olefin hydrocarbons in the presence of the catalytic system

$\text{HRh}(\text{CO})(\text{PPh}_3)_3 / (+)\text{-DIOCOL}$  are shown in the following

Table 1.

The data related to the conditions and the obtained results in asymmetric hydroformylation of various substrata by using a catalytic system comprising  $(-)\text{-DIOCOL}$  have been collected in Table 2.

TABLE 1

Asymmetric hydroformylation of olefins carried out with

(+)-DICOL as the chiral ligand

Substratum: 0.1 moles; benzene: 40 ml;

$\text{HRh}(\text{CO})(\text{PPh}_3)_3/\text{olefin} \approx 1/500$

$\text{HRh}(\text{CO})(\text{PPh}_3)_3/(+)\text{-DICOL} = 1/3$

$P_{\text{tot.}}$  80-90 atm. at ambient temperature;  $\text{CO}/\text{H}_2 = 1/1$

SUBSTRATUM	React. temp. °C	React. time hours	Conver- sion %	Yield %	Optically active compound		
					Name	A	% ee (CONF)
<u>Cis</u> -butene	80	n.d.	99	91	2-methylbuta- noic acid	100	0
2,5-dihydrofuran	60	30	99	90	tetrahydrofuran -3 carboxylic acid	100	0
styrene	80	4	45	30	2-phenylpro- panoic acid	89	1 (R)
2-phenylpropene	90	110	66	52	3-phenylbutanal	95	1 (R)

A = percent of chiral aldehyde in the reaction product

ee = enantiomeric excess

TABLE 2

Asymmetric hydroformylation of olefins carried out with  
(-)-DIOCOL as the chiral ligand.

Substratum: 0.1 moles; benzene: 40 ml

$\text{HRh}(\text{CO})(\text{PPh}_3)_3/\text{olefin} \approx 1/500$

$\text{HRh}(\text{CO})(\text{PPh}_3)_3/(-)\text{-DIOCOL} = 1/1.5$

$P_{\text{tot.}}$  80-90 atm. at ambient temperature;  $\text{CO}/\text{H}_2 = 1/1$

SUBSTRATUM	React. temp. °C	React. time hours	Conver- sion %	Yield %	Optically active compound		
					Name	A	% ee (CONF)
1-butene	60	65	98	91	2-methylbuta- noic acid	13	3.8 (R)
<u>Cis</u> -butene	90	n.d.	98	90	2-methylbutanal	100	1 (S)
2,5-dihydrofuran	60	44	99	93	tetrahydrofuran 3-carboxylic acid	100	3.3 (R)
2,3,3-trimethyl- -1-butene	100	n.d.	65	50	3,4,4-trimethyl pentanoic acid	100	1.1 (R)
styrene	80	16	92	85	2-phenylpropa- noic acid	68	6.3 (R)
2-phenylpropene	90	240	55	50	3-phenylbutanal	95	1 (S)
isoprene	80	140	98	30	3-methylpenta- noic acid	--	34.2 (S)

A = percent of chiral aldehyde in the reaction product

ee = enantiomeric excess

EXAMPLE 10Asymmetric hydrocarbomethoxylation of 3,3-dimethyl-1-butene.

8.4 Grams (0.1 moles) of 3,3-dimethyl-1-butene, 50 ml of a 4:1 (v/v) mixture of benzene/methanol, 35 mg ( $2 \times 10^{-4}$  moles) of palladium chloride and 223 mg ( $4 \times 10^{-4}$  moles) of (+)-DICOL were introduced into a 0.2 liters stainless steel autoclave. The reaction vessel was loaded with carbon monoxide at 100 atmospheres and then heated for 47 hours at 70°C. The 93% of the starting substratum was transformed into esters. By means of a fractional distillation a mixture of esters was obtained, with a yield of 80%, containing 11.4% of methyl (R)-2,3,3-trimethylbutanoate having an optical purity of 2.6%.

The reaction conditions and the results of other experiments of asymmetric hydrocarbalkoxylation carried out according to the hereinbefore described process in the presence of palladium chloride and (+)-DICOL as the catalytic system have been summarized in the following Table 3.

The reaction conditions and the results obtained in the hydrocarbomethoxylation of various substrata by using the catalytic system containing (-)-DIOCOL have been summarized in Table 4.

TABLE 3

Hydrocarbalkoxylation of olefins carried out by means of  
(+)-DICOL as the chiral ligand.

Substratum: 0.1 moles; benzene/ethanol = 4/1

$\text{PdCl}_2/\text{olefin} \approx 1/500$ ;  $\text{PdCl}_2/(+)\text{-DICOL} = 1/2$

SUBSTRATUM	React. temp. °C	React. time hours	P <sub>CO</sub> atm.	Conv. %	Yield %	Optically active compound			
						name	A	% ee	(CONF)
1-butene	70	18	140	80	65	ethyl 2-me- thylbutanoate	58.6	2	(S)
<u>Cis</u> -butene	70	41	140	85	72	ethyl-2-me- thylbutanoate	98.5	1	(R)
2,3,3-trimethyl- -1-butene	100	164	80	n.d.	33	ethyl-3,4,4- trimethyl- pentanoate	100	2.5	(R)
styrene	80	96	90	99	9	ethyl 2-phe- nylpropanoate	100	1.6	(S)
phenylpropene	100	24	95	85	-	---	0	-	

A = percent of chiral aldehyde in the reaction product

ee = enantiomeric excess e

TABLE 4

Hydrocarbalkoxylation of olefins carried out by means of

(-)-DIOCOL as the chiral ligand

Substratum: 0.1 moles; benzene/ethanol = 4/1

$\text{PdCl}_2/\text{olefin} \approx 1/500$ ;  $\text{PdCl}_2/(-)\text{-DIOCOL} = 1/1$

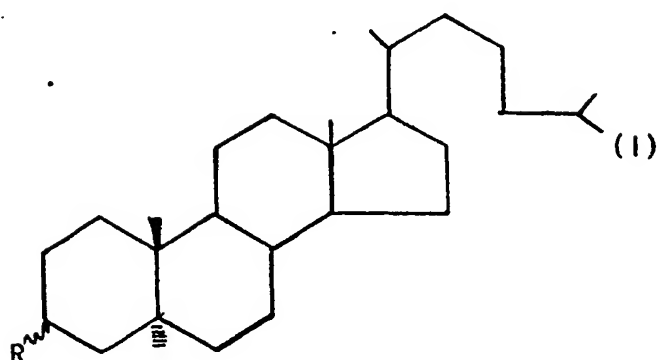
SUBSTRATUM	React. temp. °C	React. time hours	P CO atm.	Conv. %	Yield %	Optically active compound		
						name	A	% ee (CONF)
1-butene	90	15	150	98	88	ethyl 2-me- thylbutanoate	27	4.3 (S)
<u>Cis</u> -butene	100	12	140	99	91	ethyl 2-me- thylbutanoate	59.3	2.1 (R)
2,3,3-trimethyl- -1-butene	100	72	80	75	68	ethyl 3,4,4- trimethyl pentanoate	100	12.5 (S)
2-phenylpropene	120	24	80	99	95	ethyl 3-phe- nyl butanoate	100	1.3 (S)
styrene	70	47	100	99	80	ethyl 2-phe- nyl propanoate	44	6.7 (S)

A = percent of chiral aldehyde in the reaction product

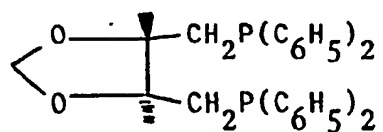
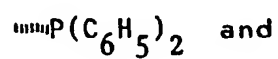
ee = enantiomeric excess

CLAIMS

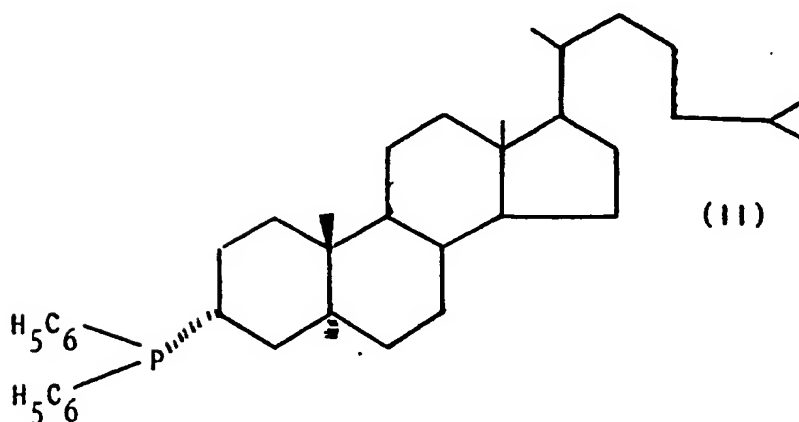
1. New steroidal chiral phosphines of formula:



wherein R represents a phosphorated group selected between

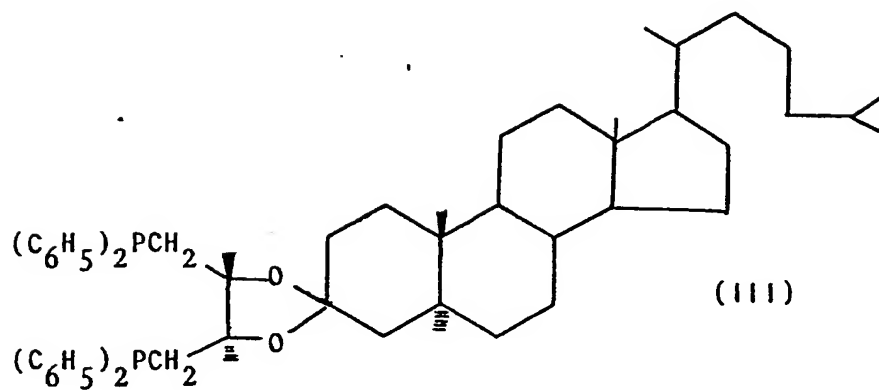


2. A compound as defined in claim 1, of formula:

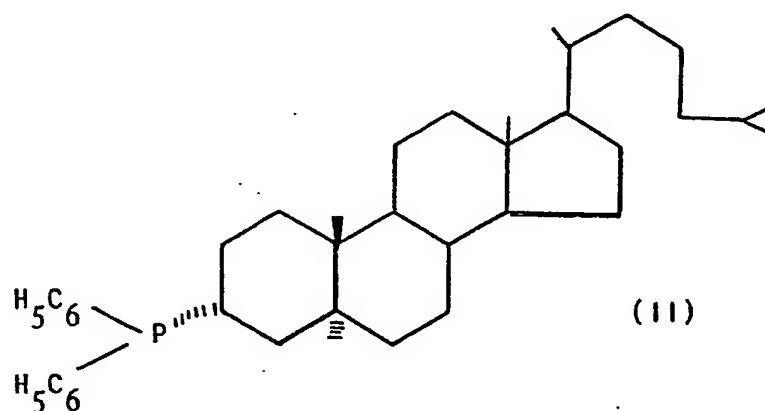




3. A compound as defined in claim 1, of formula:

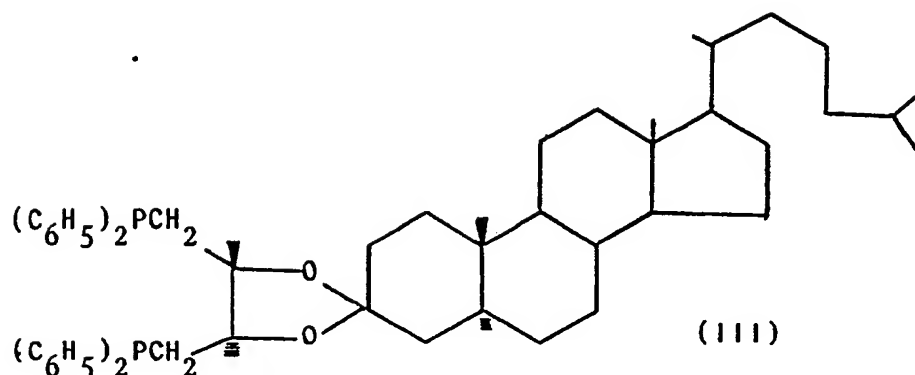


4. A process for preparing a steroidal chiral phosphine of formula



which comprises reacting the  $5\alpha$ -cholestane- $3\beta$ -ol tosylate with sodium diphenylphosphine under nitrogen atmosphere in an anhydrous inert organic solvent like dioxane or tetrahydrofuran or mixtures thereof, at room temperature for a period of time comprised between 2 and 4 days.

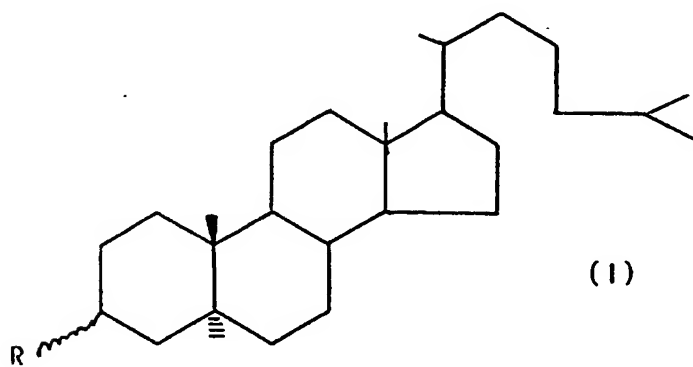
5. A process for preparing a steroidal chiral phosphine of formula:



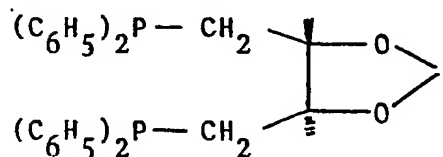
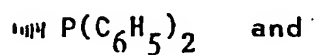
which comprises reacting the 5 $\alpha$ -cholestane-3-one with (R)(R)-diethyl tartrate in an inert organic solvent like toluene or benzene in the presence of p-toluenesulfonic acid, at the boiling temperature of the reaction mixture for a period of time comprised between 12 and 24 hours, reducing the carbethoxy groups to hydroxymethyl groups by means of a metal hydride like lithium aluminium hydride or sodium borohydride in anhydrous diethyl ether at the boiling temperature of the reaction mixture for a period of time comprised between 2 and 10 hours, protecting the hydroxy groups by reaction with p-toluenesulfonyl chloride and reacting the so obtained p-toluenesulfonyl derivative with sodium diphenylphosphine under stirring at room temperature,

in an inert organic solvent like dioxane, tetrahydrofuran or a mixture thereof, for a period of time comprised between 24 and 72 hours.

6. New catalytic systems to be employed in asymmetric homogeneous catalytic processes, comprising a suitable metal complex and a new steroidal chiral phosphine of general formula:

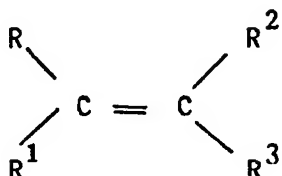


wherein R represents a phosphorated group selected from



7. A new catalytic system as defined in claim 6 characterized in that the metal complex is selected from neutral or cationic complexes of monovalent rhodium, platinum complexes and palladium complexes.

8. A process for asymmetrically hydrogenating prochiral substrata of formula

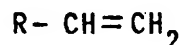


wherein R and R<sup>1</sup>, independently represent hydrogen, straight or branched (C<sub>1</sub>-C<sub>6</sub>) alkyl, substituted or unsubstituted aryl or (C<sub>3-8</sub>) cycloalkyl; R<sup>1</sup> may be also a carboxy group;

R<sup>2</sup> represents a carboxy, an ester or an amide group;

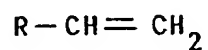
R<sup>3</sup> represents (C<sub>1-6</sub>) alkyl, (C<sub>3-8</sub>) cycloalkyl, a substituted or unsubstituted aryl group or an amide group characterized in that catalytic systems are used, comprising a neutral or cationic complex of monovalent rhodium and a ligand as defined in claim 1.

9. A process for asymmetrically hydroformylating prochiral substrata of formula



wherein R represents a straight or branched aliphatic group containing from 1 to 20 carbon atoms or a substituted or unsubstituted aryl group, characterized in that catalytic systems are used, comprising a rhodium or platinum complex and a ligand as defined in claim 1.

10. A process for asymmetrically hydrocarbalkoxylating prochiral substrata of formula:

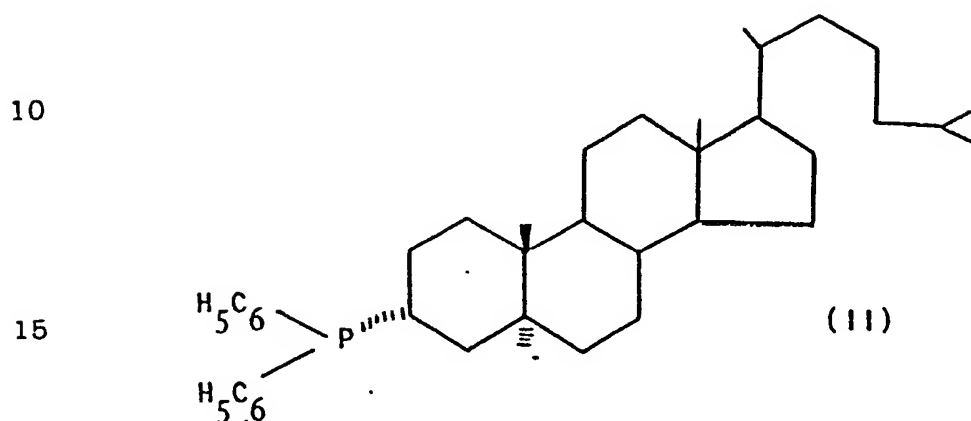


wherein R represents a straight or branched aliphatic group containing from 1 to 20 carbon atoms or a substituted or unsubstituted aryl group, characterized in that catalytic systems are used, comprising a palladium complex and a ligand as defined in claim 1.

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CLAIMS FOR AUSTRIA

- 5 1. A process for preparing a steroidal chiral phosphine  
of formula

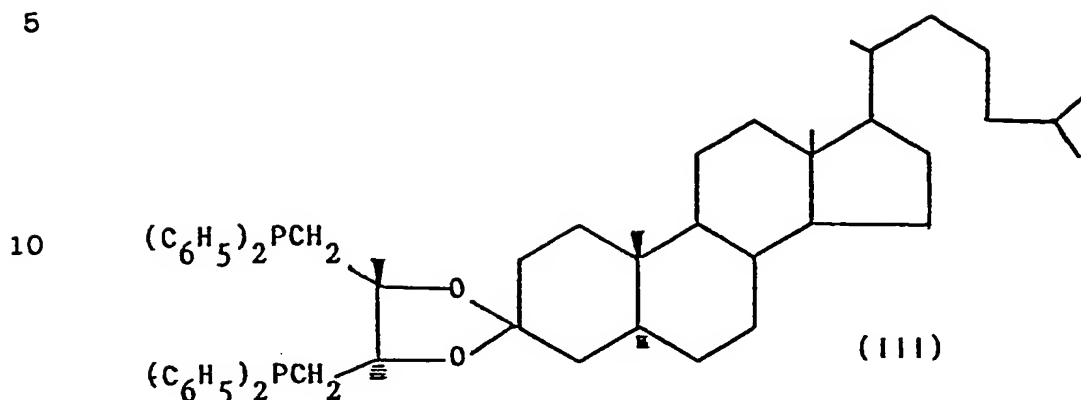


which comprises reacting the 5α-cholestan-3β-ol  
20 tosylate with sodium diphenylphosphine under nitrogen  
atmosphere in an anhydrous inert organic solvent like  
dioxane or tetrahydrofuran or mixtures thereof, at room  
25 temperature for a period of time comprised between 2  
and 4 days.

30

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- 1 2. A process for preparing a steroidal chiral phosphine  
of formula:

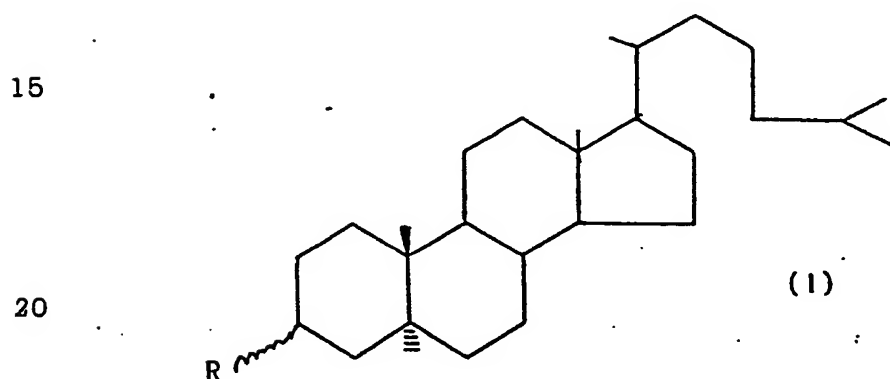


15

which comprises reacting the 5 $\alpha$ -cholestane-3-one  
with (R)(R)-diethyl tartrate in an inert organic solvent  
like toluene or benzene in the presence of p-toluenesul-  
20 fonic acid, at the boiling temperature of the reaction  
mixture for a period of time comprised between 12 and  
24 hours, reducing the carbethoxy groups to hydroxy-  
25 methyl groups by means of a metal hydride like lithium  
aluminium hydride or sodium borohydride in anhydrous  
diethyl ether at the boiling temperature of the reaction  
30 mixture for a period of time comprised between 2 and  
10 hours, protecting the hydroxy groups by reaction  
with p-toluenesulfonyl chloride and reacting the so  
35 obtained p-toluenesulfonyl derivative with sodium di-  
phenylphosphine under stirring at room temperature,

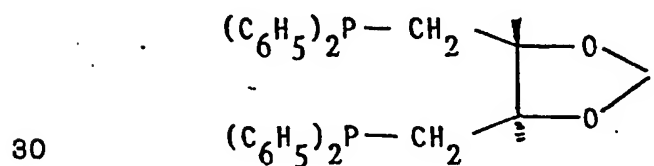
1 in an inert organic solvent like dioxane, tetrahydro-  
 furan or a mixture thereof, for a period of time com-  
 5 prised between 24 and 72 hours.

3. A process for preparing new catalytic systems to be employed in asymmetric  
 homogeneous catalytic processes, comprising mixing a suitable  
 metal complex and a new steroidal chiral phosphine of  
 10 general formula:



20 wherein R represents a phosphorated group selected from

25  $\text{H}_2\text{P}(\text{C}_6\text{H}_5)_2$  and



4. A process as defined in claim 3 charac-

terized in that the metal complex is selected from

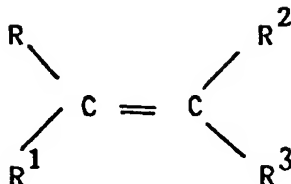
35 neutral or cationic complexes of monovalent rhodium,

platinum complexes and palladium complexes.



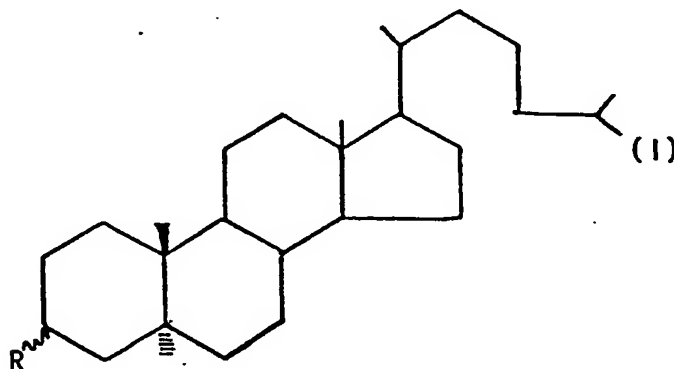
1 5. A process for asymmetrically hydrogenating prochiral  
substrata of formula

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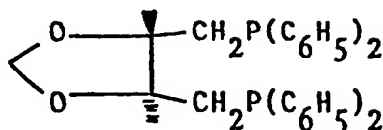
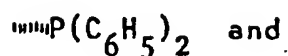
10 wherein R and R<sup>1</sup>, independently represent hydrogen,  
straight or branched (C<sub>1</sub>-C<sub>6</sub>) alkyl, substituted or un-  
substituted aryl or (C<sub>3</sub>-8) cycloalkyl; R<sup>1</sup> may be also  
15 a carboxy group;  
R<sup>2</sup> represents a carboxy, an ester or an amide group;  
R<sup>3</sup> represents (C<sub>1</sub>-6) alkyl, (C<sub>3</sub>-8) cycloalkyl, a sub-  
20 stituted or unsubstituted aryl group or an amide group  
characterized in that catalytic systems are used, com-  
prising a neutral or cationic complex of monovalent rho-  
dium and as a ligand a new steroidal chiral phosphine of  
25 formula

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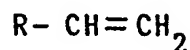


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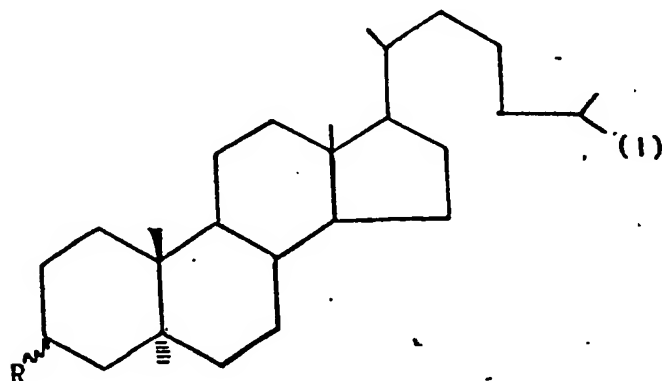
wherein R represents a phosphorated group selected between



6. A process for asymmetrically hydroformylating prochiral substrata of formula

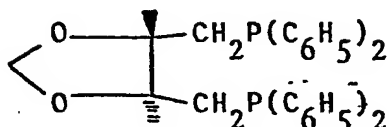


wherein R represents a straight or branched aliphatic group containing from 1 to 20 carbon atoms or a substituted or unsubstituted aryl group, characterized in that catalytic systems are used, comprising a rhodium or platinum complex and as a ligand a new steroidal chiral phosphine of formula



1 wherein R represents a phosphorated group selected  
between

5  $\text{P}(\text{C}_6\text{H}_5)_2$  and



10

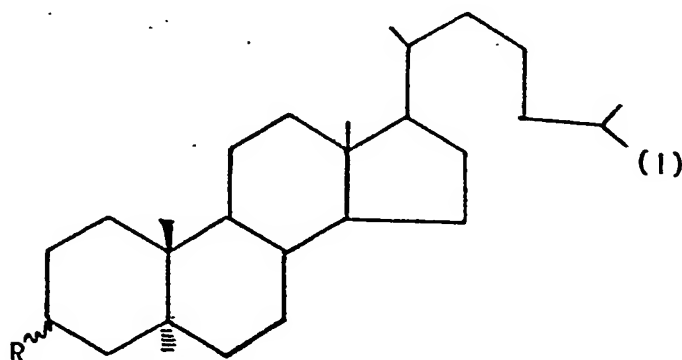
7. A process for asymmetrically hydrocarbalkoxylating  
prochiral substrata of formula:

15  $\text{R}-\text{CH}=\text{CH}_2$

wherein R represents a straight or branched aliphatic  
group containing from 1 to 20 carbon atoms or a substi-  
tuted or unsubstituted aryl group, characterized in  
20 that catalytic systems are used, comprising a palladium  
complex and as a ligand a new steroidal chiral phos-  
phine of formula

25

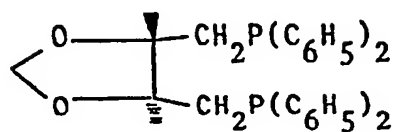
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1 wherein R represents a phosphorated group selected  
between

5  $\text{P}(\text{C}_6\text{H}_5)_2$  and



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European Patent  
Office

# EUROPEAN SEARCH REPORT

0081149

Application number

EP 82 11 0879

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)
A	CHEMICAL ABSTRACTS, vol. 86, no. 19, 9th May 1977, page 593, no. 140339t, Columbus Ohio (USA); Y.NAGAO et al.: "Organophosphorus compounds. 83. The varied chemical behaviors of quaternary phosphonium salts with 3beta- and 3alpha-linked cholesterol residues as ligands in electrochemical reduction phosphine oxide cleavage, and hydrogenolysis with lithium aluminum hydride". & PHOSPHORUS 1976, 6(3-4), 139-46. *Abstract*	1,2	C 07 J 51/00 B 01 J 31/24 C 07 B 1/00 C 07 C 45/49 C 07 C 45/50 C 07 C 67/38
A	EP-A-0 000 403 (F.HOFFMANN LA ROCHE) *Claims*	6,7,8	
A,D	DE-A-2 359 101 (PROF. PIERO PINO) *Claims*	6,7,9	TECHNICAL FIELDS SEARCHED (Int. Cl. 3)  C 07 J 51/00 C 07 F 9/00
A	EP-A-0 028 378 (UNION CARBIDE CORP.) *Claims*	6,7,9	
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 22-02-1983	Examiner HENRY J.C.
<p>CATEGORY OF CITED DOCUMENTS</p> <p>X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document</p> <p>T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons &amp; : member of the same patent family, corresponding document</p>			



European Patent  
Office

# EUROPEAN SEARCH REPORT

0081149

Application number

EP 82 11 0879

Page 2

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)
P	JOURNAL OF ORGANOMETALLIC CHEMISTRY, vol. 229, no. 1, 13th April 1982, pages 93-100, Elsevier Sequoia S.A., Lausanne (CH); G.CAVINATO et al.: "Hydrocarboalkoxylation of N-Vinylphthalimide catalyzed by palladium complexes". *The whole article*  -----	1-7,10	
			TECHNICAL FIELDS SEARCHED (Int. Cl. 7)
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 22-02-1983	Examiner HENRY J.C.
<b>CATEGORY OF CITED DOCUMENTS</b>			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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